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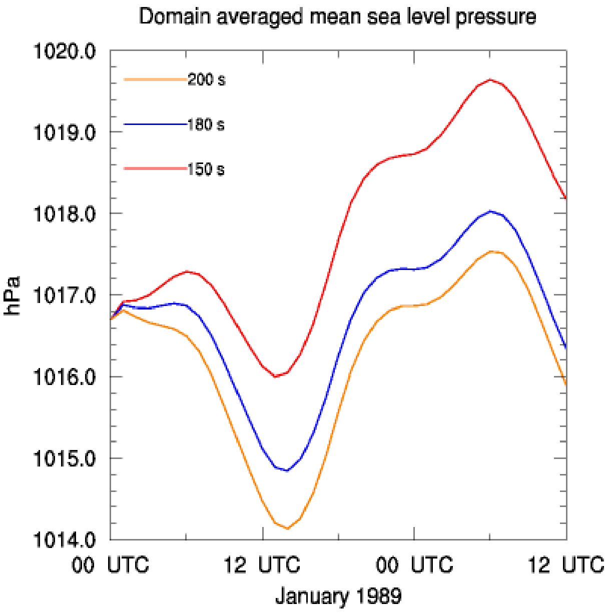
The day after tomorrow

Short introduction

The CLM Community faces problems with simulations using a specific time step for simulations over the CORDEX region (Africa). The problem has been reported by B. Rockel, but similar problems have been reported for simulations over India (A. Dobler). The simulation using 150 sec time step produces deviations of 2 hPa after 36 hours lead time (see Figure). The problem does not occur with other timestep values. Here the budget tool (implemented in V4.8) is used to better understand the cause for these deviations, at least in terms of temperature.

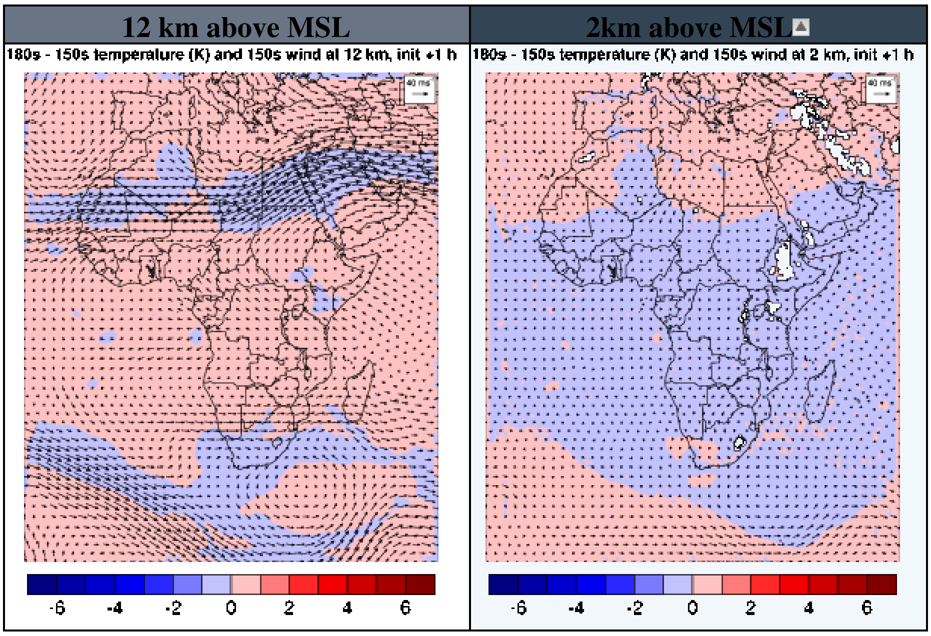
The tool extracts both physical and dynamical temperature and moisture tendencies. Two options are available: (1) development (2) physical interpretation. Option (1) extracts temperature tendencies and this also for the fast-mode tendency. The 3d advection is identical to the used one and the net heating is exactly maid up by the single contributing tendencies. With option (2) potential temperature tendencies are extracted. 3d advection is estimated using an additional theta advection in the code. Therefore, the net budget is not totally closed, but too a very good approximation. For both options vertical advection in z-direction is calculated/estimated online using 2nd-order centered differences. Here, the exact budget will be analyzed using option (1). The tool has been implemented in version 4.8_clm8, but the bug which was reported by Hans-Jürgen Panitz concerning the distribution of itheta_adv has been fixed here.



Animations of temperature difference

Temperature difference (180s - 150s) at 12 km MSL and 2 km MSL for the simulations using B. Rockel's standard setup. With red colors indicating a too cold dt=150 sec run! The temperature deviations are strongest right below the Rayleigh sponge. Within the relaxation layer the errors seem to be relaxed to the background temperature and are very small at the very top model level (not shown). After some hours delay a temperature deviation of opposite sign (dt=150 sec too warm) also establishes close to the surface.

12 km above MSL	2km above MSL



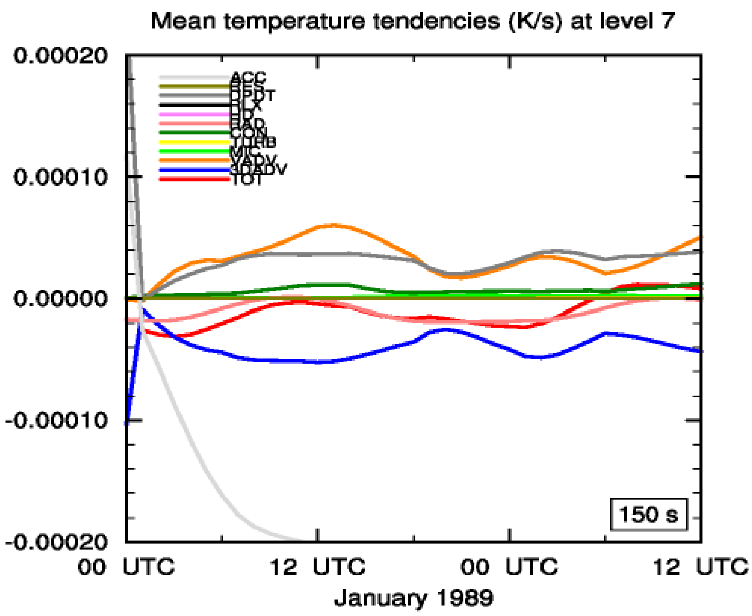
Evolution of domain mean T-tendencies at several model levels

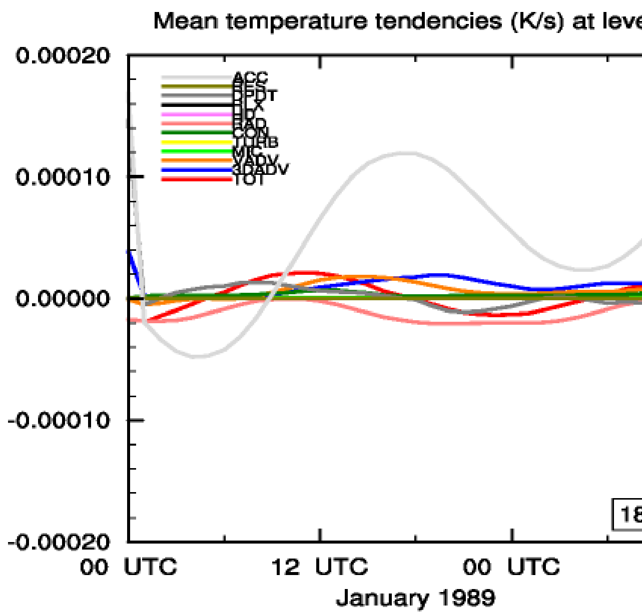
Model level 7 (counted from top downwards) is the first level without relaxation. The setup is the standard (B. Rockel) setup. Focusing on the very beginning of the simulations, to things appear different between the two standard simulations:

1. The initial fast-mode tendency (dark gray) is slightly higher in the dt=150 sec run.
2. The initial 3D advection (blue) has opposite sign (negative) in the dt=150 sec run.

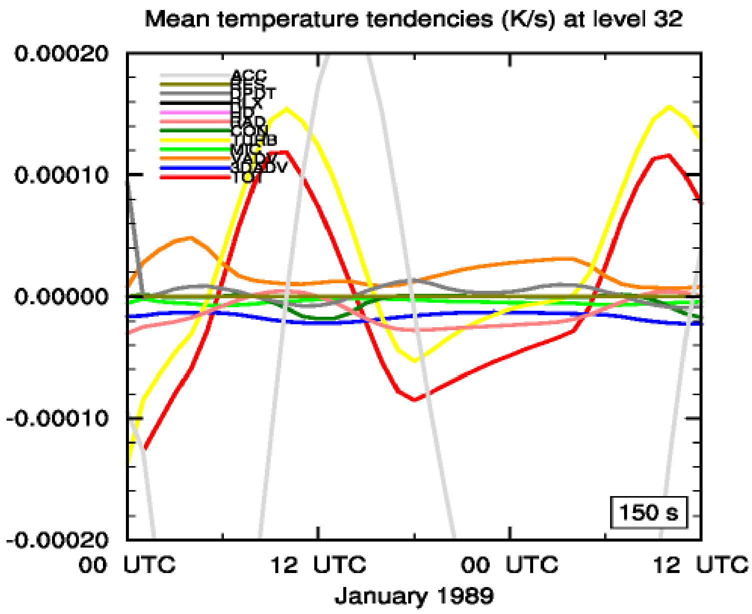
The net heating (dark red) on this level is lower with dt=150 sec than with dt=180 sec, which leads to the above shown temperature deficit in ~12 km. This can be seen here also from the accumulated net tendencies (light gray) curves. Only two candidates can cause the cold deviations: **Advection or fast-mode!**

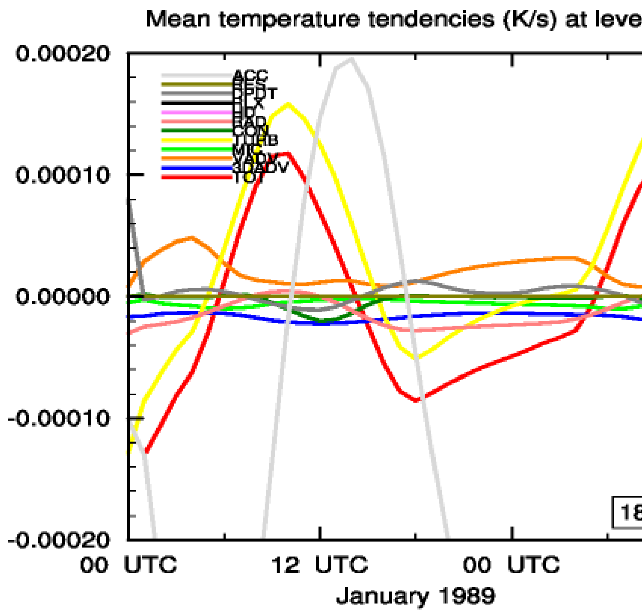
Since vertical advection tendencies are of positive sign (heating), the stronger cooling, if caused by advection, must be caused by horizontal advection.





At the surface level the differences between the two simulations are small in general. The net tendencies (dark red) are dominated by the turbulence flux divergence (yellow) and the radiation (light red), which show a typical diurnal cycle. The heat provided by turbulence is removed subsequently by convective upward directed fluxes (dark green). The microphysics tendencies (light green) are negative, indicating the dominating effect of evaporation close to the surface. The estimation of the vertical advection tendency indicates heating by subsidence during night-time. The accumulated net tendencies are slightly higher at the end of the simulation (36 hours) in the case of dt=150 seconds.





Legend:

red : net

blue : 3d advection

gray : fast-mode

black : Rayleigh damping

pink : horizontal diffusion

light red : radiation

yellow : turbulence

light green : microphysics

dark green : convection

light gray : accumulated net tendency

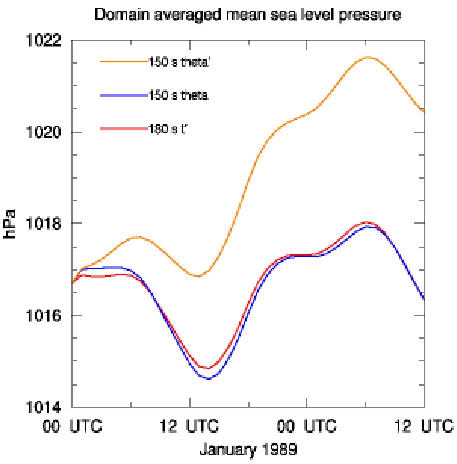
brown : residual (=0, no tendency, but a check)

orange : estimated vertical advection

Tests:

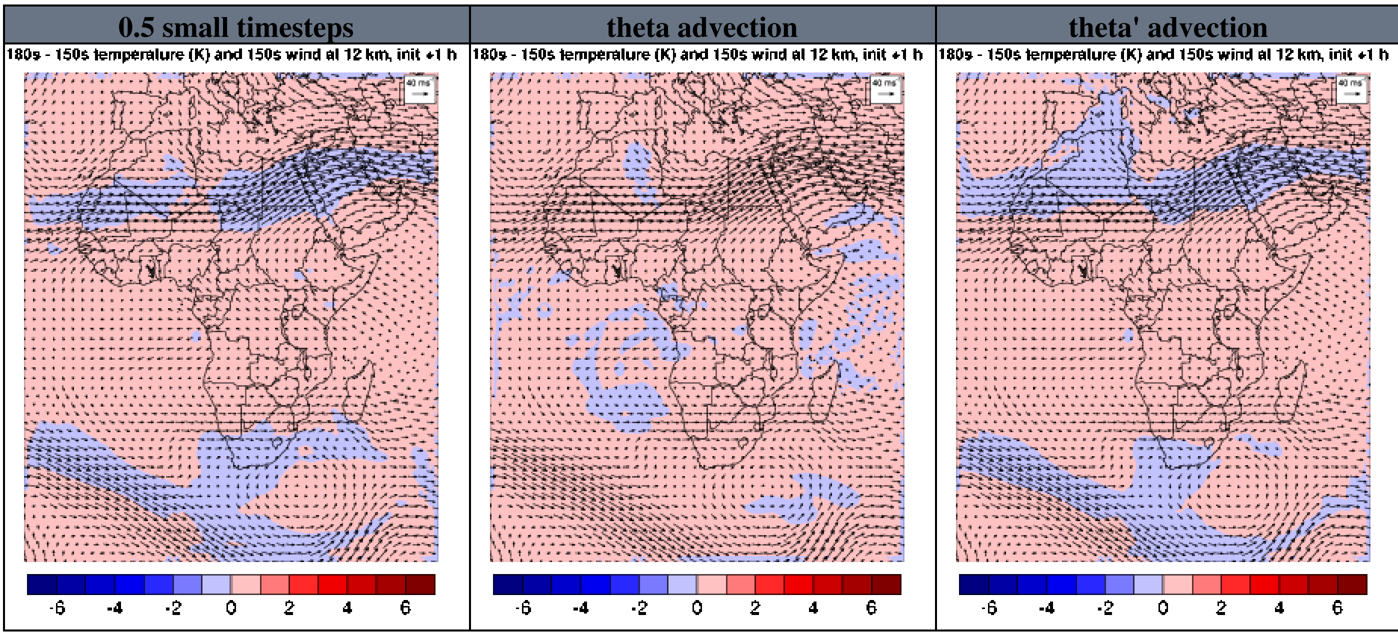
1) Temperature/Theta advection

The Figure below shows that with theta advection instead of the previously used t' advection the problem with dt=150 s can be solved. The resulting surface pressure is then close to the results from dt = 180 sec run. However, using theta' advection results in as even worse behavior of the surface pressure.



Temperature difference (180s - 150s) at 12 km MSL for different simulations using a timestep of 150 sec. Red colors indicating a too cold 150 sec run! The previous section should that either advection or the fast-mode causes the strong upper-level cooling. Two tests are shown here to investigate this:

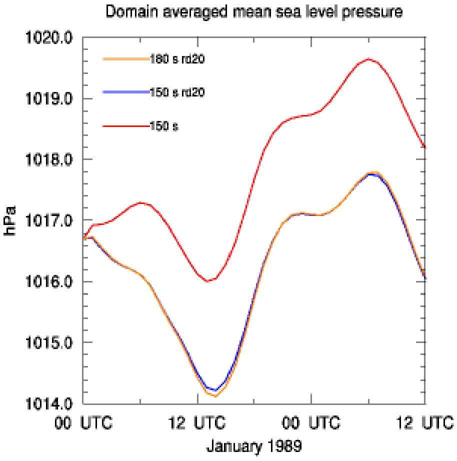
1. the small timesteps (1st-3rd) are halved
2. full potential temperature advection instead of t' advection
3. potential temperature deviation advection instead of t' advection



Advection of the deviation of the potential temperature fails, aswell. The simulation using full theta advection inseat of t' advection does not reveal strong systematic deviations. The decrease of the small timestep size causes an enhancement of the bias, indicating that the fast-mode influences this deviation. Since switching to the advection of full potential temperature involves also a different treatment within the fast-mode (no vert. advection of mean state necessary then?), the reason for the success of full theta advection is still unclear.

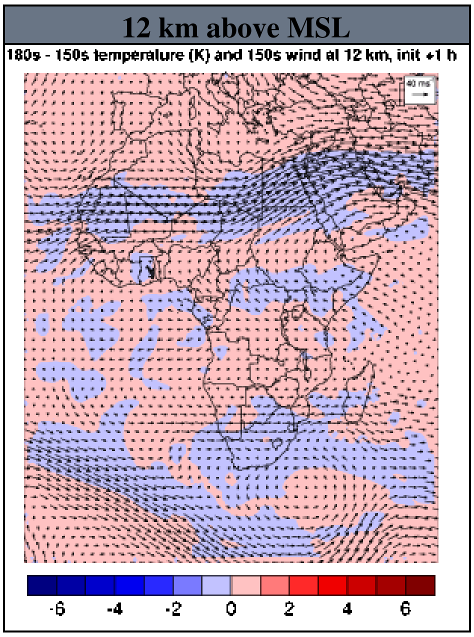
2) Rayleigh-Sponge thickness

Some more tests are performed which have already been conducted by Hans-Jürgen Panitz. For these runs rdheight=20000 (rd20) decreases the depth of the wave-absorbing layer to the two uppermost model levels. The setup is applied for simulations using dt = 180 s and dt = 150 s, respectively, and the t' advection.The resulting surface pressure is shown in the Figure below.



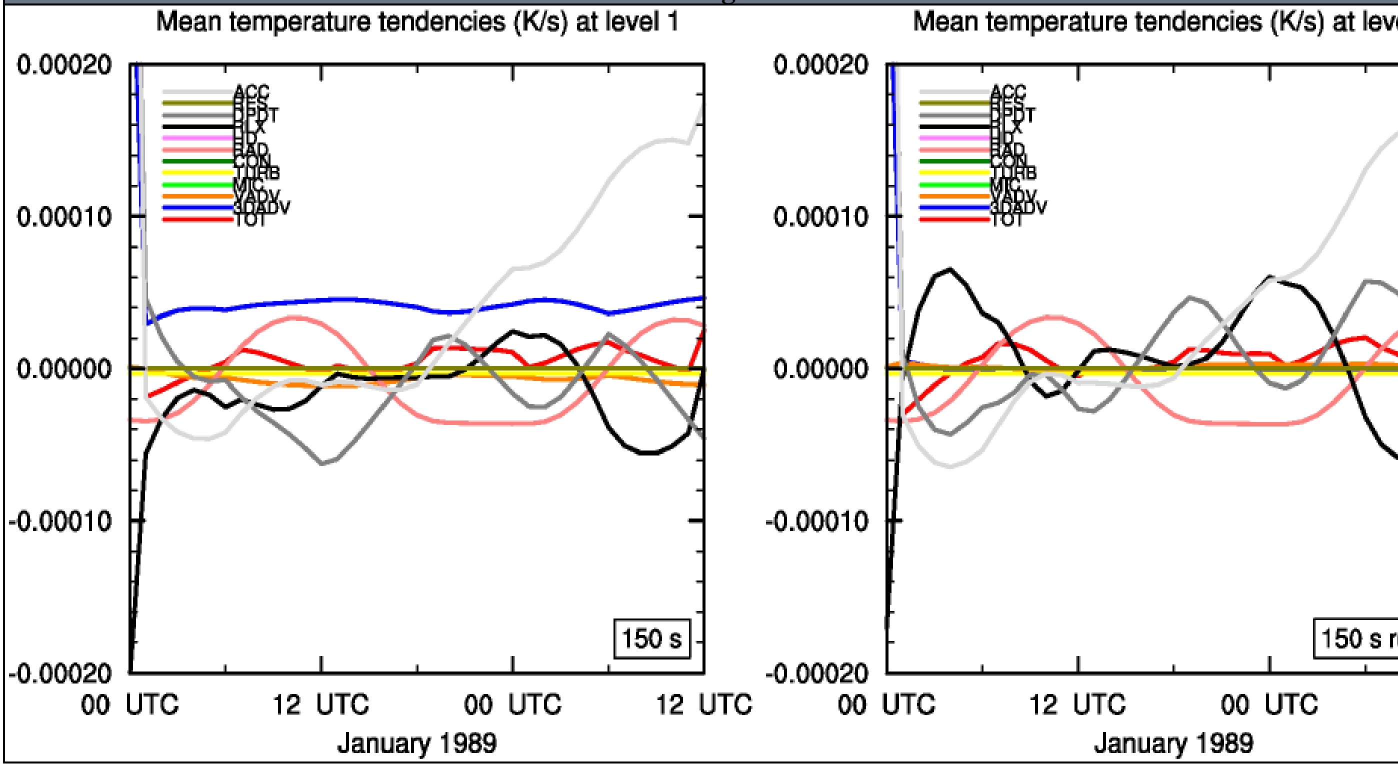
Obviously, the timestep dependence vanishes using a smaller depth of the damping layer, since the evolution of mean pressure is almost identical for these runs. The deviations to the 150 s run with a deep sponge become clear as well.

The animation shows the temperature difference between the 150 s and 180 s runs using rd20. The differences disappear.

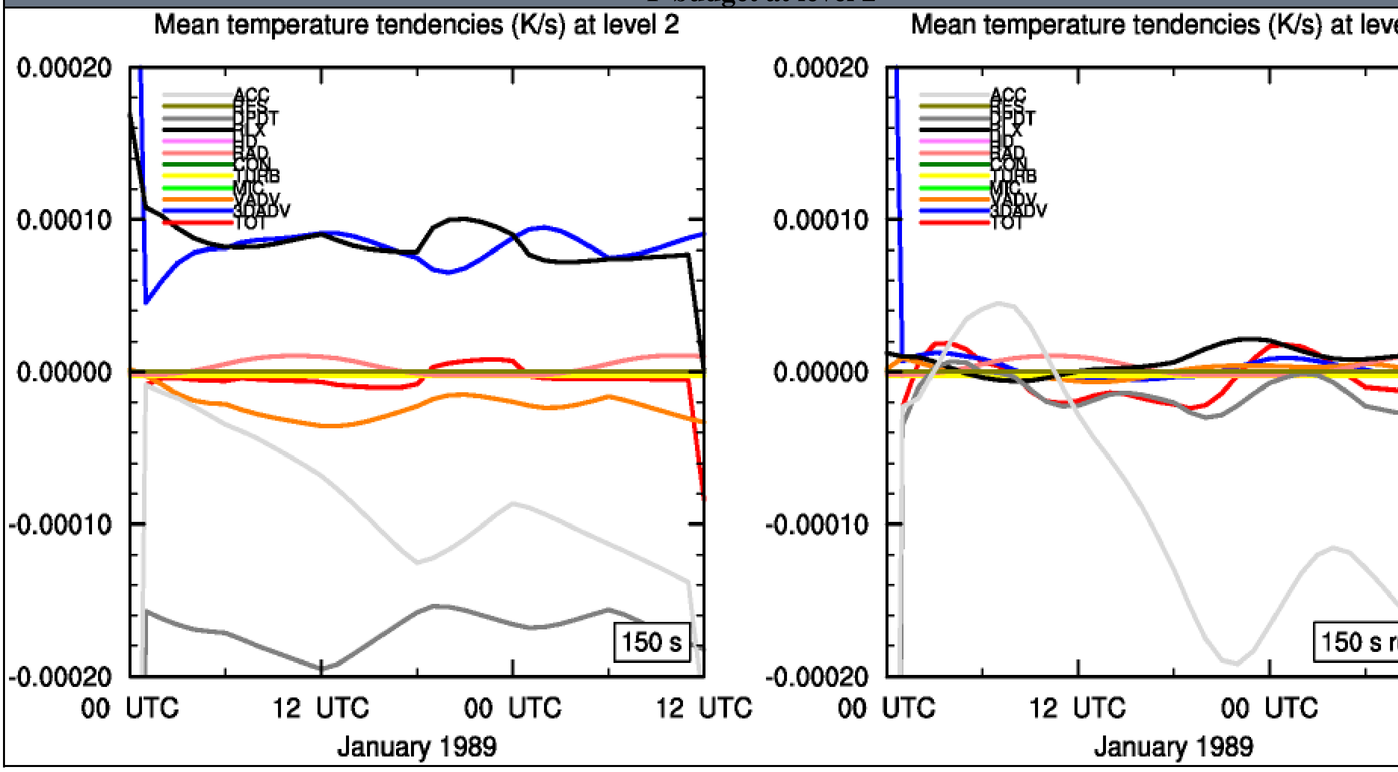


Again, the tendencies are analyzed for several levels close to the model's top. The evolution of the tendencies is shown for the simulations using dt = 150 s with different setups of the sponge. For the run with large layer thickness (left) the advection appears to contribute substantially on level 1, but compensation by other tendencies results in similar accumulated net effects. On level 2 relaxation, fast-mode and advection are the largest tendencies, while on model level 3 only advection and relaxation dominate. The run with rd20 produces smaller tendencies for advection and also for fast-mode tendencies. Only level 1 and 2 are affected by relaxation.

T-budget at level 1

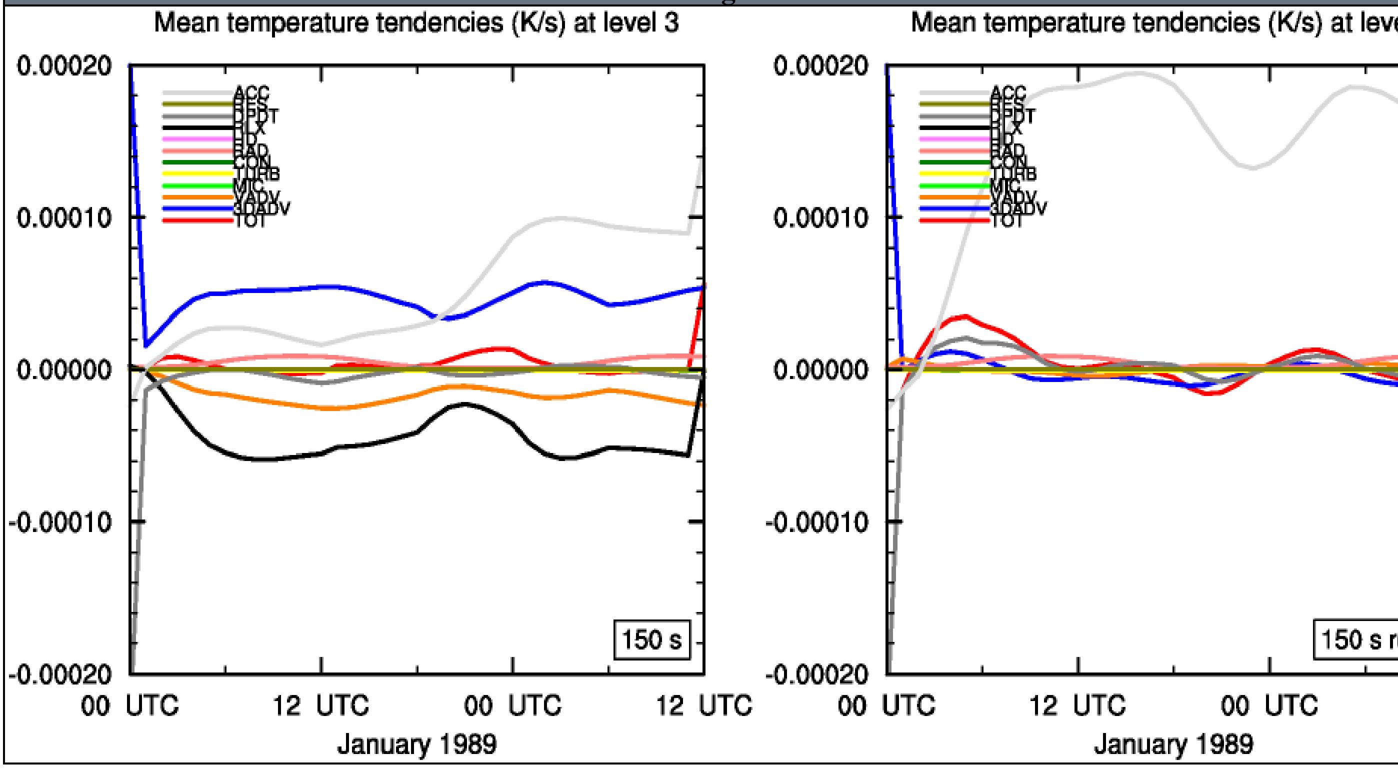


T-budget at level 2



T-budget at level 3

T-budget at level 3



Conclusions

The advection of theta sloves the problem!

Cause for failing of t' advection: to be clarified!

With rd=20000. the problem disappears as well

-- WolfgangLanghans - 17 Dec 2009

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